

Near-threshold J/Ψ production in proton–nucleus collisions

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Abstract

We study the J/Ψ production from nuclei near the kinematic threshold within the collision model, based on the nuclear spectral function, for incoherent primary proton–nucleon charmonium creation processes. The model takes into account the initial proton and final J/Ψ absorption, target nucleon binding and Fermi motion, the formation length of J/Ψ mesons as well as the effect of their nuclear mean-field potential on these processes. We calculate the A dependences of the absolute and relative (transparency ratio) charmonium yields as well as its excitation function within the different scenarios for the $J/\Psi N$ absorption cross section, for the J/Ψ formation length and for J/Ψ in-medium modification. We demonstrate that the former observables, on the one hand, are not practically affected by the charmonium formation length effects and, on the other hand, they are appreciably sensitive to the genuine $J/\Psi N$ absorption cross section at beam energies of interest, which means that these observables can be useful to help determine the above cross section from the comparison of the results of our calculations with the future data from the CBM experiment at FAIR—the upcoming accelerator facility at GSI-Darmstadt, Germany. We also show that the excitation function for J/Ψ subthreshold production in pA reactions reveals some sensitivity to adopted its in-medium modification scenarios. Therefore, such observable may be an important tool to get valuable information on the charmonium in-medium properties.

1. Introduction

An extensive investigations of the charmonium production and suppression in relativistic proton–nucleus and nucleus–nucleus collisions have been carried out over the last years (see, for example, [1–11]). From these studies one hopes to extract valuable information about both the strength of the inelastic J/Ψ –nucleon interaction and a possible formation of a quark-gluon plasma in these collisions, in-medium properties of charmonium states. However, in high-energy collisions the J/Ψ mesons are produced with high momenta relative to the nuclear medium, which does not allow one to put strong constraints on the genuine charmonium–nucleon absorption cross section from the existing experimental data due to the substantial J/Ψ formation time effects. There are essentially less extensive investigations [12–17] of the production and absorption of the charmonium states in antiproton–nucleus reactions at low energies, where they are created with the moderate momenta relative to the target nucleus and where, therefore, the J/Ψ formation length effects play a minor role. Finally, the production of J/Ψ mesons on nuclei in proton-induced reactions at low energies [18–20] and, especially, at energies close to their kinematic threshold (the threshold kinetic energy for J/Ψ production in pp collisions being 11.3 GeV) [11, 21] has up to now received very little consideration, probably, because of the lack of suitable facilities and associated detectors. Since the cross sections of $(p, J/\Psi)$ reaction at near-threshold energies are expected to be extremely low, high intensity proton beams are needed to perform accurate measurements of J/Ψ creation on nuclear targets in the threshold region. Such measurements are planned to be conducted in the near future in the upcoming compressed baryonic matter (CBM) experiment at the Facility for Anti-proton and Ion Research (FAIR).

The main aim of the present work is to get the estimates of the absolute and relative yields of J/Ψ mesons and their excitation functions from pA collisions in the near-threshold energy region in the framework of the first collision model based on the nuclear spectral function. In view of the future data from FAIR experiments, these estimates can be used as an important tool for understanding the role of the conventional cold nuclear matter effects in J/Ψ production in nuclear collisions at various beam energies.

2. First collision model

Since we are interested in the near-threshold bombarding energy region up to 14 GeV, we have taken into consideration the following elementary processes, which have the lowest free production threshold (≈ 11.3 GeV)¹⁾ :

$$p + p \rightarrow p + p + J/\Psi, \quad (1)$$

$$p + n \rightarrow p + n + J/\Psi. \quad (2)$$

It is expected [22–26] that the J/Ψ mass shift at saturation density ρ_0 is only of the order of a few MeV due to a small coupling of the c , \bar{c} quarks to the nuclear medium. However, in Ref. [27] Sibirtsev and Voloshin have shown within the multipole expansion and low-energy theorems in QCD that this mass shift is significantly larger ($-\Delta m_{J/\Psi} \geq 21$ MeV) than previously estimated in the literature and might be observed experimentally. So, it is unclear currently what J/Ψ in-medium mass shift is the correct one. The knowledge of this shift is important for distinguishing between different models [22–27] and, hence, for gaining more insight into the dynamics of low-energy QCD. Accounting for mentioned above, in the following calculations we will include the

¹⁾We can neglect in the energy domain of our interest the following two-step J/Ψ production processes with χ_{c1} , χ_{c2} and Ψ' mesons in an intermediate states: $pN \rightarrow pN\chi_{c1}$, $pN \rightarrow pN\chi_{c2}$, $pN \rightarrow pN\Psi'$; $\chi_{c1} \rightarrow J/\Psi\gamma$ (BR = 36%), $\chi_{c2} \rightarrow J/\Psi\gamma$ (BR = 20%), $\Psi' \rightarrow J/\Psi\pi\pi$ (BR = 49%) and $\Psi'N \rightarrow J/\Psi N$ due to larger χ_{c1} , χ_{c2} and Ψ' production thresholds in pN collisions—13.6, 13.9 and 14.6 GeV, respectively.

medium modification of the J/Ψ mesons, participating in the production processes (1), (2), by using, for reasons of simplicity, their average in-medium mass $\langle m_{J/\Psi}^* \rangle$ defined as:

$$\langle m_{J/\Psi}^* \rangle = \int d^3r \rho_N(\mathbf{r}) m_{J/\Psi}^*(\mathbf{r}) / A, \quad (3)$$

where $\rho_N(\mathbf{r})$ and $m_{J/\Psi}^*(\mathbf{r})$ are the local nucleon density and J/Ψ effective mass inside the nucleus, respectively. Assuming that

$$m_{J/\Psi}^*(\mathbf{r}) = m_{J/\Psi} + V_0 \frac{\rho_N(\mathbf{r})}{\rho_0}, \quad (4)$$

we can readily rewrite equation (3) in the form

$$\langle m_{J/\Psi}^* \rangle = m_{J/\Psi} + V_0 \frac{\langle \rho_N \rangle}{\rho_0}. \quad (5)$$

Here, $m_{J/\Psi}$ is the J/Ψ free space mass and $\langle \rho_N \rangle$ is the average nucleon density. Our calculations show that, for example, for target nuclei ^{12}C and ^{93}Nb the ratio $\langle \rho_N \rangle / \rho_0$ is approximately equal to 0.5 and 0.7, respectively. We will use these values throughout the following study. In it for the J/Ψ mass shift at saturation density V_0 we will employ the four following options: i) $V_0 = 0$, ii) $V_0 = -50$ MeV, iii) $V_0 = -100$ MeV, and iv) $V_0 = -150$ MeV. For the reason of reducing the possible uncertainty of our calculations due to the use in them of the model nucleon [28, 29] self-energies at high momenta, we will ignore the medium modification of the outgoing nucleon mass in the present work.

Then, taking into account the distortion of the incident proton and the absorption of the final J/Ψ meson as well as the fact that in the near-threshold energy region of our interest the produced J/Ψ meson moves in the nucleus substantially in the forward direction and using the results given in [16, 30, 31], we can represent the total ²⁾ cross section for the production of J/Ψ mesons off nuclei in the primary proton-induced reaction channels (1), (2) as follows:

$$\sigma_{pA \rightarrow J/\Psi X}^{(\text{prim})}(T_0) = I_V[A] \langle \sigma_{pN \rightarrow pNJ/\Psi}(T_0) \rangle_A, \quad (6)$$

where

$$I_V[A] = 2\pi A \int_0^R r_\perp dr_\perp \int_{-\sqrt{R^2-r_\perp^2}}^{\sqrt{R^2-r_\perp^2}} dz \rho(\sqrt{r_\perp^2+z^2}) \quad (7)$$

$$\times \exp \left[-\sigma_{pN}^{\text{in}} A \int_{-\sqrt{R^2-r_\perp^2}}^z \rho(\sqrt{r_\perp^2+x^2}) dx - A \int_z^{\sqrt{R^2-r_\perp^2}} \sigma_{J/\Psi N}^{\text{eff}}(x-z) \rho(\sqrt{r_\perp^2+x^2}) dx \right],$$

$$\langle \sigma_{pN \rightarrow pNJ/\Psi}(T_0) \rangle_A = \int \int P_A(\mathbf{p}_t, E) d\mathbf{p}_t dE \sigma_{pN \rightarrow pNJ/\Psi}(\sqrt{s}, \langle m_{J/\Psi}^* \rangle) \quad (8)$$

and

$$s = (E_0 + E_t)^2 - (\mathbf{p}_0 + \mathbf{p}_t)^2, \quad (9)$$

$$E_t = M_A - \sqrt{(-\mathbf{p}_t)^2 + (M_A - m_N + E)^2}. \quad (10)$$

Here, $\sigma_{pN \rightarrow pNJ/\Psi}(\sqrt{s}, \langle m_{J/\Psi}^* \rangle)$ is the "in-medium" total cross section for the production of J/Ψ with reduced mass $\langle m_{J/\Psi}^* \rangle$ in reactions (1) and (2) ³⁾ at the pN center-of-mass energy \sqrt{s} ; $\rho(\mathbf{r})$

²⁾In the full phase space without any cuts on angle and momentum of the observed J/Ψ meson.

³⁾In equation (6) it is assumed that the J/Ψ meson production cross sections in pp and pn interactions are the same.

and $P_A(\mathbf{p}_t, E)$ are the local nucleon density and the spectral function of target nucleus A normalized to unity ⁴⁾; \mathbf{p}_t and E are the internal momentum and binding energy of the struck target nucleon just before the collision; σ_{pN}^{in} is the inelastic cross section ⁵⁾ of the free pN interaction; A is the number of nucleons in the target nucleus, M_A and R are its mass and radius; m_N is the bare nucleon mass; \mathbf{p}_0 , E_0 and T_0 are the momentum, total and kinetic energies of the initial proton; $\sigma_{J/\Psi N}^{\text{eff}}(z)$ is the J/Ψ -nucleon effective absorption cross section, which will be defined below. The quantity $I_V[A]$ in equation (6) represents the effective number of target nucleons participating in the primary $pN \rightarrow pNJ/\Psi$ reactions.

Following [31, 32], we assume that the "in-medium" cross section $\sigma_{pN \rightarrow pNJ/\Psi}(\sqrt{s}, < m_{J/\Psi}^* >)$ for J/Ψ production in reactions (1) and (2) is equivalent to the vacuum cross section $\sigma_{pN \rightarrow pNJ/\Psi}(\sqrt{s}, m_{J/\Psi})$ in which the free mass $m_{J/\Psi}$ is replaced by the average in-medium mass $< m_{J/\Psi}^* >$ as given by equation (5). For the free total cross section $\sigma_{pN \rightarrow pNJ/\Psi}(\sqrt{s}, m_{J/\Psi})$ we have used the parametrization ⁶⁾ from [3, 5] that has been corrected for the proper threshold behavior with accounting for the lowest data point from [19] taken at 24 GeV/c incident proton momentum, viz.:

$$\sigma_{pN \rightarrow pNJ/\Psi}(\sqrt{s}, m_{J/\Psi}) = \begin{cases} \frac{2.37}{0.0597} \left(1 - \frac{m_{J/\Psi}}{\sqrt{s}}\right)^{12} [\text{nb}] & \text{for } \sqrt{s} > 10 \text{ GeV}, \\ 528 \left(1 - \frac{m_{J/\Psi} + 2m_N}{\sqrt{s}}\right)^{5.225} [\text{nb}] & \text{for } m_{J/\Psi} + 2m_N \leq \sqrt{s} \leq 10 \text{ GeV}. \end{cases} \quad (11)$$

Let us focus now on the charmonium-nucleon effective cross section $\sigma_{J/\Psi N}^{\text{eff}}(z)$, entering into the equation (7), which takes into account the time dependence of the J/Ψ formation. Following [13, 16, 33], we express this cross section in terms of a J/Ψ meson formation length $l_{J/\Psi}$:

$$\sigma_{J/\Psi N}^{\text{eff}}(z) = \sigma_{J/\Psi N} \left\{ \theta(l_{J/\Psi} - z) \left[\frac{z}{l_{J/\Psi}} + \frac{n^2 < k_t^2 >}{m_{J/\Psi}^2} \left(1 - \frac{z}{l_{J/\Psi}}\right) \right] + \theta(z - l_{J/\Psi}) \right\}. \quad (12)$$

Here, $\sigma_{J/\Psi N}$ is the genuine free-space J/Ψ -nucleon absorption cross section; n is the number of valence quarks of the hadron ($n = 2$ in our case), while $< k_t^2 >^{1/2}$ is the average transverse momentum of the quark in the hadron (taken to be $< k_t^2 >^{1/2} = 0.35 \text{ GeV}/c$); z is the distance from the $c\bar{c}$ -pair production point and $\theta(x)$ is the standard step function. For the J/Ψ meson formation length $l_{J/\Psi}$ we adopt the conventional formula with an energy denominator [13, 16, 33]:

$$l_{J/\Psi} \simeq \frac{2p_{J/\Psi}^{\text{lab}}}{m_{\Psi'}^2 - m_{J/\Psi}^2}, \quad (13)$$

where $p_{J/\Psi}^{\text{lab}}$ is the charmonium momentum in the target nucleus rest frame. Taking into consideration that the momentum $p_{J/\Psi}^{\text{lab}} \simeq 7.6 \text{ GeV}/c$ in the process $pN \rightarrow pNJ/\Psi$ occurring on a free target nucleon being at rest at threshold energy of 11.3 GeV, one can get that $l_{J/\Psi} \simeq 0.8 \text{ fm}$ for this momentum. We will use this value for the quantity $l_{J/\Psi}$ throughout our calculations for a collection of A target nucleons subject to Fermi motion in the near-threshold energy domain. As is easy to see from formula (12), when J/Ψ formation length $l_{J/\Psi} \rightarrow 0$ then the effective cross section $\sigma_{J/\Psi N}^{\text{eff}}(z) \rightarrow \sigma_{J/\Psi N}$, which means that in this case the "normal" J/Ψ absorption in nuclear matter is recovered. It should be noticed that the second exponent in equation (7) can be put in view of equation (12) in the following in an easy-to-use in numerical integration form:

$$A \int_z^{\sqrt{R^2 - r_\perp^2}} \sigma_{J/\Psi N}^{\text{eff}}(x - z) \rho(\sqrt{r_\perp^2 + x^2}) dx = \sigma_{J/\Psi N} A \theta(\sqrt{R^2 - r_\perp^2} - z - l_{J/\Psi}) \quad (14)$$

⁴⁾The specific information about used in our subsequent calculations these quantities is given in [30, 31].

⁵⁾We use $\sigma_{pN}^{\text{in}} = 30 \text{ mb}$ in our present calculations.

⁶⁾It should be pointed out that this parametrization describes the inclusive $pp \rightarrow J/\Psi X$ cross section which is assumed to be the same as that for $pN \rightarrow pNJ/\Psi$ at beam energies of interest.

$$\times \left\{ \int_z^{l_{J/\Psi}+z} \left[\frac{x-z}{l_{J/\Psi}} + \alpha(n) \left(1 - \frac{x-z}{l_{J/\Psi}} \right) \right] \rho(\sqrt{r_\perp^2 + x^2}) dx + \int_{l_{J/\Psi}+z}^{\sqrt{R^2 - r_\perp^2}} \rho(\sqrt{r_\perp^2 + x^2}) dx \right\} \\ + \sigma_{J/\Psi N} A \theta(l_{J/\Psi} + z - \sqrt{R^2 - r_\perp^2}) \int_z^{\sqrt{R^2 - r_\perp^2}} \left[\frac{x-z}{l_{J/\Psi}} + \alpha(n) \left(1 - \frac{x-z}{l_{J/\Psi}} \right) \right] \rho(\sqrt{r_\perp^2 + x^2}) dx,$$

where $\alpha(n) = n^2 < k_t^2 > / m_{J/\Psi}^2$ ($\alpha(2) = 0.0511$).

The absorption cross section $\sigma_{J/\Psi N}$ can be extracted, in particular, from a comparison of the calculations with the measured transparency ratio of the J/Ψ meson, normalized, for example, to carbon:

$$T_A = \frac{12}{A} \frac{\sigma_{pA \rightarrow J/\Psi X}}{\sigma_{pC \rightarrow J/\Psi X}}. \quad (15)$$

Here, $\sigma_{pA \rightarrow J/\Psi X}$ and $\sigma_{pC \rightarrow J/\Psi X}$ are inclusive total cross sections for J/Ψ production in pA and pC collisions, respectively. If the primary proton-induced reaction channels (1), (2) dominate in the J/Ψ production in pA reactions close to threshold⁷⁾, then, according to (6) and (7), we have:

$$T_A = \frac{12}{A} \frac{I_V[A] \langle \sigma_{pN \rightarrow pN J/\Psi}(T_0) \rangle_A}{I_V[C] \langle \sigma_{pN \rightarrow pN J/\Psi}(T_0) \rangle_C}. \quad (16)$$

Ignoring the medium effects⁸⁾, from (16) we approximately obtain:

$$T_A \approx \frac{12}{A} \frac{I_V[A]}{I_V[C]}. \quad (17)$$

The integral (7) for $I_V[A]$ in the case of a nucleus of a radius $R = r_0 A^{1/3}$ with a sharp boundary and in the limit $l_{J/\Psi} \rightarrow 0$ has the following simple form [34]:

$$I_V[A] = \frac{3A}{(a_1 - a_2)a_2^2} \left\{ 1 - (1 + a_2)e^{-a_2} - \left(\frac{a_2}{a_1} \right)^2 [1 - (1 + a_1)e^{-a_1}] \right\}, \quad (18)$$

where $a_1 = 3A\sigma_{J/\Psi N}/2\pi R^2$ and $a_2 = 3A\sigma_{pN}^{\text{in}}/2\pi R^2$. The simple formulas (17), (18) allow one to easily estimate the transparency ratio T_A at well above threshold energies.

Let us discuss now the results of our calculations in the framework of the approach outlined above.

3. Results

Figure 1 shows the A -dependence of the total J/Ψ production cross section from the primary $pN \rightarrow pN J/\Psi$ reaction channels in pA ($A = {}^{12}\text{C}$, ${}^{27}\text{Al}$, ${}^{40}\text{Ca}$, ${}^{93}\text{Nb}$, ${}^{208}\text{Pb}$, and ${}^{238}\text{U}$) collisions calculated for incident proton kinetic energy of $T_0 = 14$ GeV on the basis of equations (6) and (7) for different values of the genuine charmonium-nucleon absorption cross section $\sigma_{J/\Psi N}$, as indicated in the inset, and for no J/Ψ mass shift. While the calculations with only $l_{J/\Psi} = 0$

⁷⁾One may expect that this is so due to the following. The main inelastic channel in pN collisions at beam energies of interest is the multiplicity production of pions with comparatively low energies at which the secondary $\pi N \rightarrow J/\Psi X$ processes are energetically suppressed.

⁸⁾These effects lead to only small corrections to the ratio T_A at above threshold incident energies. They are within several percent here, as our calculations by (16) and (17) for the nucleus with a diffuse boundary showed. However, the medium effects become substantial at subthreshold beam energies, as our calculations also demonstrated.

in equation (7) are given in the figure for $\sigma_{J/\Psi N} = 7$ mb and $\sigma_{J/\Psi N} = 14$ mb, for the case of $\sigma_{J/\Psi N} = 3.5$ mb the ones are presented here already for two options, namely: i) $l_{J/\Psi} = 0$ and ii) $l_{J/\Psi} = 0.8$ fm. A choice of $\sigma_{J/\Psi N} = 3.5$ mb has been particularly motivated by the results from the J/Ψ photoproduction experiment at SLAC [35, 36], while the value of $\sigma_{J/\Psi N} = 7$ mb⁹⁾ was dictated by the analyses of the observed suppression of J/Ψ in nuclear collisions within the various models [1, 5, 6] based on J/Ψ absorption by hadrons. Finally, an option of $\sigma_{J/\Psi N} = 14$ mb was motivated by the findings of [11], indicating that the charmonium–nucleon absorption cross section can be larger than ≈ 10 mb at FAIR energies¹⁰⁾. One can see that the results are practically insensitive to the

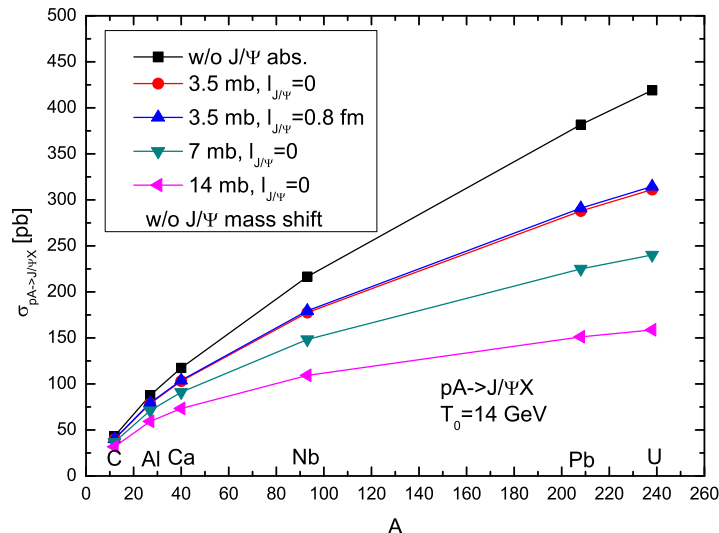


Figure 1: A-dependence of the total cross section of J/Ψ production by 14 GeV protons from primary $pN \rightarrow pNJ/\Psi$ channels in the full phase space in the scenario without J/Ψ mass shift for different values of the $J/\Psi N$ absorption cross section and J/Ψ formation length indicated in the inset. The lines are included to guide the eyes.

J/Ψ formation time effects. On the other hand, they depend strongly, especially for heavy target nuclei, on the charmonium–nucleon absorption cross section. Looking at this figure, we see also that for the incoming proton energy of 14 GeV of our interest the value of the absolute J/Ψ meson yield is of the order of 100–400 pb for targets heavier than the Al target in employed four scenarios for the cross section $\sigma_{J/\Psi N}$. This value is very small, but one might expect to measure it in the future FAIR experiments. Therefore, we can conclude that the observation of the A dependence, like that just considered, can serve as an important tool to determine the genuine $J/\Psi N$ absorption cross section.

In figure 2 we show our predictions for the transparency ratio T_A , defined by equation (15) and calculated using the results presented in the above figure, as a function of the nuclear mass number A for initial proton energy of 14 GeV. It can be seen that, contrary to the preceding case, there are no differences between the results obtained by adopting different J/Ψ formation lengths under consideration. Whereas, we may observe in this figure the experimentally separated differences (~ 20 –30%) between all calculations corresponding to different options for the $J/\Psi N$ absorption

⁹⁾It should be mentioned that the $J/\Psi N$ inelastic cross section of the order of 6–8 mb is reported in recent calculations [37] adopting effective Lagrangians.

¹⁰⁾It is interesting to note in this connection that the cross section of the J/Ψ –nucleon elastic scattering at the threshold was found in [27] to be most likely larger than 17 mb.

cross section only for targets heavier than the Ca target, where they are less than $\sim 10\%$, which means that this observable is well suited to determine the cross section $\sigma_{J/\Psi N}$ and the future data from the CBM experiment for it performed using the heavy targets (Nb, Pb) should help to distinguish between these options.

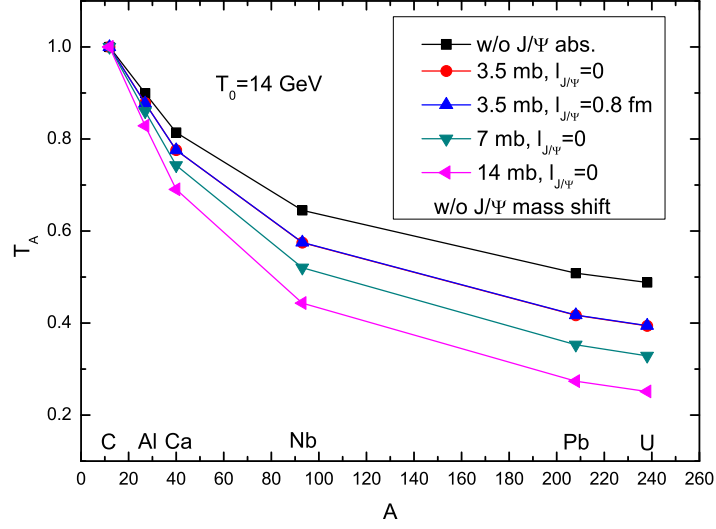


Figure 2: Transparency ratio T_A for J/Ψ mesons as a function of the nuclear mass number A in the scenario without their mass shift as well as for their different absorption cross sections and formation lengths indicated in the inset. The lines are included to guide the eyes.

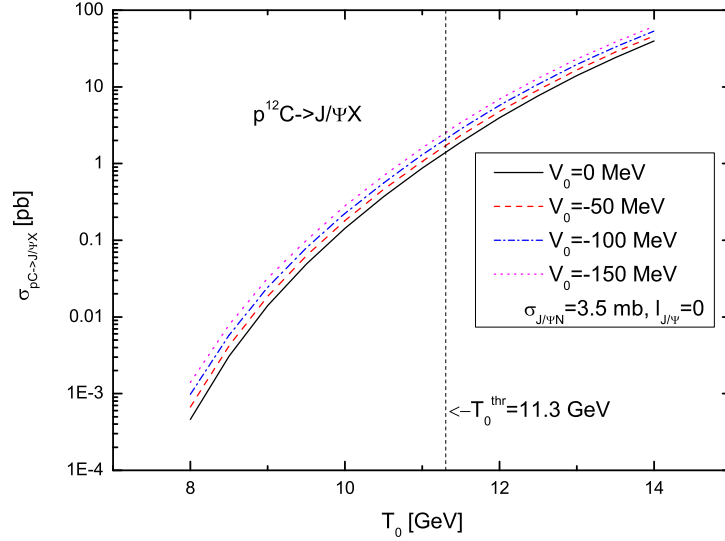


Figure 3: Excitation function for production of J/Ψ mesons off ^{12}C . The curves are calculations for $\sigma_{J/\Psi N} = 3.5 \text{ mb}$ and $l_{J/\Psi} = 0$ with an in-medium J/Ψ mass shift depicted in the inset. The vertical dashed line indicates the threshold energy for J/Ψ production on a free nucleon.

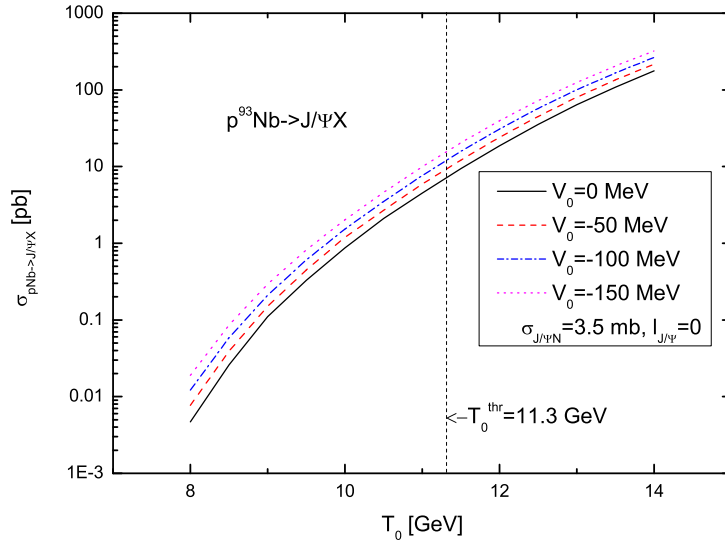


Figure 4: The same as in figure 3, but for the ^{93}Nb target nucleus.

Finally, we consider the excitation functions for production of J/Ψ mesons off ^{12}C and ^{93}Nb target nuclei. They were calculated on the basis of equation (6) for $\sigma_{J/\Psi N} = 3.5$ mb and $l_{J/\Psi} = 0$ as well as for four adopted scenarios for the J/Ψ in-medium mass shift, and are given in figures 3 and 4. One can see that in the far subthreshold region ($T_0 \sim 8\text{--}10$ GeV) there are well separated predictions for these considered scenarios for the J/Ψ in-medium mass shift. The values of the total charmonium production cross sections in this region are very small (in the range of 0.01–1 pb), but one might expect to measure them in the future FAIR experiments as well. Therefore, these measurements might help to get definite information about this shift. It should be noticed that an analogous possibility has been discussed before for the photoproduced ω [38] and η' [31] mesons, and it was very recently realized for the η' mesons in [39].

Taking into account the above considerations, we come to the conclusion that such observables as the absolute and relative (transparency ratio) J/Ψ meson yields from pA interactions as well as its excitation function can be useful at proton beam energies close to the kinematic threshold to help determine both the genuine $J/\Psi N$ absorption cross section and a possible charmonium mass shift in cold nuclear matter.

4. Conclusions

In this paper we have calculated the A dependence of the absolute and relative cross sections for J/Ψ production from pA collisions at 14 GeV beam energy by considering incoherent primary proton–nucleon charmonium production processes in the framework of a nuclear spectral function approach, which accounts for the struck target nucleon momentum and removal energy distribution, elementary cross section for proton–nucleon reaction channel close to threshold as well as different scenarios for the genuine $J/\Psi N$ absorption cross section and its formation length. Also we have calculated the excitation function for J/Ψ production off ^{12}C and ^{93}Nb target nuclei in the near-threshold energy regime. It was found that the A dependence of the absolute and relative J/Ψ yields at incident energy of interest, on the one hand, is practically not influenced by formation length effects and, on the other hand, it is appreciably sensitive to the charmonium–nucleon absorption cross section. This gives a nice opportunity to determine it experimentally. It was also

shown that the excitation function for J/Ψ production off nuclei is well sensitive to the possible J/Ψ in-medium mass shift at subthreshold beam energies, and this offers the possibility to investigate the shift via J/Ψ production on light and heavy target nuclei at these energies.

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